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Learning about carbon capture and storage: Changing stakeholder perceptions with expert information

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Abstract

Carbon capture and storage (CCS) technology has the potential to contribute to reductions in atmospheric carbon dioxide emissions and thus help mitigate climate change. Although awareness of the potential of CCS technology is increasing among the public and specific energy/climate stakeholders, understanding remains limited and engaged opportunities for learning about CCS technology have been minimal. This paper explores stakeholders' perceptions of the risks and benefits of CCS technology, and how those perceptions changed with additional information provided by CCS technology experts. In October 2007, a unique day-long CCS educational event was held at the Chewonki Foundation's Center for Environmental Education in Wiscasset, Maine, U.S.A. This event brought a dozen CCS experts from academia, industry, and government to Maine to discuss CCS technology, its potential role in mitigating CO_2 emissions, and its place within the evolution of an increasingly carbon constrained energy system. Approximately one hundred key policy and decision-makers with interest and involvement in the northeast United States' energy system were invited and participated in the seminar. All participants were asked to complete a survey on their perceptions of the risks and benefits of CCS technology before and after the event. The results indicate that exposure to information about CCS technology increased stakeholder reporting of their level of understanding of the technology and of their level of support for advancing the technology. Several interesting changes in perception were associated with age, level of education and gender. Significant changes in the reported level of support for CCS advancement was found in more educated and younger stakeholders while this change did not appear with older and less educated individuals. A distinct and significant increase was identified in the level of concern about CCS reported among women before and after the event.

CCS; learning; experts; surveys; public acceptance; public perception

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1. Introduction

Carbon captures and storage (CCS) is increasingly considered to be a technology with potential critical contribution to a carbon-constrained energy future (IPCC 2005; MIT 2007). Advancing carbon management technologies, including CCS, depends on a complex array of socio-political factors which can be influenced by stakeholder perceptions of the risks and benefits of the technologies. Given the increasing sense of urgency for CO_2 emissions reductions, coupled with the current trend of increasing societal reliance on fossil fuel based energy, interest in CCS technologies from both the public and private sector has grown rapidly in the past decade (Stephens 2006). Despite this growth, several recent studies demonstrate limited public and stakeholder understanding about CCS technology (Reiner, Curry et al. 2006; Shackley, Waterman et al. 2007). One reason for limited understanding and awareness about CCS is the fact that support for communication and outreach on CCS is limited, and engaged opportunities for learning about CCS have been minimal (Reiner 2008).

As the need for communication strategies related to CCS and other emerging energy technologies is being identified, there is a growing area of research exploring communication challenges associated with communicator expertise and trustworthiness, media representation, and comparative public attitudes and public perceptions. A few recent studies have explored how the media portrays and discusses CCS (Bradbury and Dooley 2004; Alphen, Voorst et al. 2007).

Perceptions and opinions about CCS have been studied using several methods. Most common are survey tools that ask the general public what they know and think about CCS (Palmgren, Bruin et al. 2004; Reiner, Curry et al. 2006; Tokushige, Akimoto et al. 2006; Shackley, Waterman et al. 2007). Another approach to understanding public perception recognizes the limits of survey tools on topics with limited general awareness and provides detailed information with a questionnaire; this approach known as information-choice questionnaires provides a context for responding to specifically designed questions about CCS (de Best-Waldhober 2006).

Recognizing the limited opportunities for analyzing learning about CCS, this study is designed to assess how energy stakeholders respond to an intensive and focused day-long educational seminar on CCS that happened in Wiscasset, Maine, in the north-east United States in October of 2007. This paper presents the results of a set of surveys administered to attendees of this seminar. The seminar was hosted by the Chewonki Foundation, a local non-profit environmental education organization (Richardson 2007). At this event, a set of CCS experts presented and discussed different aspects of CCS technology.[2] After introducing this seminar and the motivation for it, we describe the design of the surveys that were administered to the seminar attendees. We then present the results of the surveys and some statistical analysis and interpretations of those results.

2. The Chewonki Foundation Carbon Capture and Storage Seminar Event

In early 2007, a power-plant project called The Twin River Energy Center was proposed to be located in Wiscasset, Maine, United States. The project was to be a gasification facility to be fueled with both coal and wood biomass. The proposed site in this small town on the coast of Maine is attractive for a power plant because of the existing transmission and rail infrastructure as well as the site's history; the former Maine Yankee nuclear power plant was previously located on this site, and prior to that a coal-fired power plant had been located there. During public debate about the proposed project, concerns about carbon dioxide emissions were expressed and the potential for CCS technology to reduce CO_2 emissions emerged as part of the public discourse related to the Twin River Energy Center proposed project. In response to the discussion about the potential for CCS to be incorporated into the proposed plant at some point in the future, the Chewonki Foundation organized and hosted a day-long educational seminar on CCS technology. This event took place on October 24, 2007.

The seminar was organized to inform decision-makers and the public about CCS technology in a general way. The seminar was not intended to focus on the controversial proposed power plant; the expressed goal of the seminar was to "*Provide key stakeholders, decision-makers, and the public with information regarding carbon capture and storage technologies and opportunities"* (Chewonki Foundation 2007). Over 100 state and local energy-related stakeholders accepted invitations from the Chewonki Foundation to attend the seminar, in which a set of CCS experts – from industry, academia, and government – presented, discussed, and answered questions on various aspects of CCS technology and its role as one technological option within a portfolio of climate mitigation

[2] The first two authors of this paper participated as experts in the event.

technologies. While attendance at the day-long seminar required an invitation, a shorter event, which was open to the public, was also held that evening. A subset of the experts who presented during the day-seminar were available to answer questions and informally discuss CCS with the community during the evening session. This evening session provided an opportunity for members of the local community to engage with the experts and ask specific questions about CCS technology.

3. Methods: Survey Design, Implementation, and Analysis

Every participant of the day-long seminar was given and was asked to complete two short surveys, each on a single, two-sided sheet of paper: one pre-event survey and one post-event survey. The participants were asked to fill out the pre-event survey as they entered the seminar, and to return the post-event survey as they left the seminar. All of the surveys were coded to assure that all respondents remained anonymous and that no personally identifiable information was collected. Post-event surveys were only accepted by those who stayed for the entire day-long seminar.

The survey questions were chosen to elicit information about how the participants perceived different aspects of CCS technology and its deployment, and how those perceptions changed as a result of attending the seminar. The first section asked four questions:

1. I understand the basic idea of carbon capture and storage technology.
2. I support the advancement of carbon capture and storage technology.
3. I have concerns about the advancement of carbon capture and storage technology.
4. Carbon capture and storage should be encouraged **only** as part of a larger strategy (including conservation, efficiency, and renewable energy) to reduce carbon dioxide emissions.

Respondents answered these questions by circling a number that reflected the level of their agreement to each of the statements on a scale of 1 to 5 (1=disagree completely, 5=agree completely).[3]

The second section of the surveys contained open-response questions. In the pre-event survey these questions asked participants to articulate and explain their perceptions of CCS' advantages, disadvantages, concerns specific to Maine, and their profession. In the post-event survey, the open-response section asked participants what they learned during the seminar, and again asked to describe their perceptions of CCS' advantages and disadvantages, and concerns specific to Maine:

Pre-event:

5. In general, what benefits or advantages do you think carbon capture and storage technology might offer?
6. In general, what risks or disadvantages do you associate with carbon capture and storage technology?
7. Do you have concerns about carbon capture and storage **specific** to Maine? If so, what are your concerns?
8. What is your profession (scientist, lawyer, educator, etc.)?

Post-event:

5. What did you learn during today's event, and what was most surprising?
6. In general, what benefits or advantages do you think carbon capture and storage might offer?
7. In general, what risks or disadvantages do you associate with carbon capture and storage?
8. Do you have concerns about carbon capture and storage **specific** to Maine? If so, what are they?

The surveys also had a third section with multiple choice answers that elicited demographic data about the participants, including age, gender, education level, political orientation, and the capacity in which they were attending the seminar.

This paper only includes analysis of the quantitative responses to the first and third section of the surveys. Qualitative analysis of the responses to the second section of the survey will be presented in a subsequent paper.

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[3] 1 = Disagree completely; 2 = Somewhat disagree; 3 = Neutral; 4 = Somewhat agree; 5 = Agree completely.

Two statistical tests were applied to the data collected from the first four questions: the Wilcoxen signed-rank test and pairwise correlations. The Wilcoxen signed-rank test determines whether or not respondents' answers on the pre-event survey were significantly different from their answers on the post-event survey. This test provides insight on whether or not a stakeholder changed his or her perception and opinion of CCS technology as a result of attending the seminar. The pairwise correlations indicate the general strength and relationship between answers on different questions in the population as a whole. Both tests are also used to investigate if the responses are correlated with, and/or attributable to, the underlying demographics of the respondents. In investigating the potential differences due to demographics, we limit our analysis to age, gender, and education level because these are the demographic data that can be categorized and placed along a spectrum (i.e. data on political affiliation can not be analyzed in this way because the responses are discrete categories rather than segments of a spectrum).

4. Results

Of the estimated 100 attendees at the seminar, 89 participants completed the pre-event survey and 57 of those participants also completed and returned a post-event survey. The responses to the demographic questions are shown in **Figure 1**. Attendees of the seminar were highly educated (most of them had graduate degrees), and a majority were over 40 years old. There was wide diversity in occupation, and most respondents identified themselves as either democrats or independents.

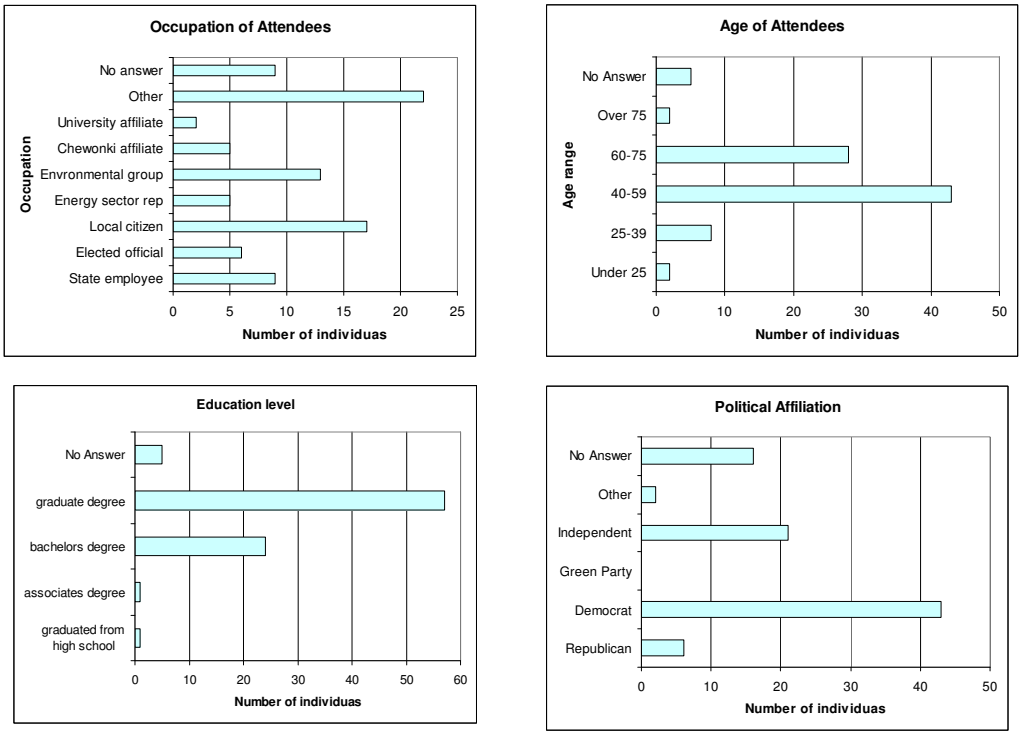

Figure 1: Demographic information reported in the surveys administered to participants of the CCS seminar.

Figure 2 shows the responses to the four quantitative questions. The responses to question #1 indicate that respondent's understanding of CCS technology increased during the seminar (Wilcoxen, $p<1\%$, $n=57$). Given the extensive series of presentations and discussions throughout the day, this result would be expected. There were

opportunities after each expert presentation for attendees to ask questions of the presenters, so enhanced clarity and levels of understanding about CCS is not surprising.

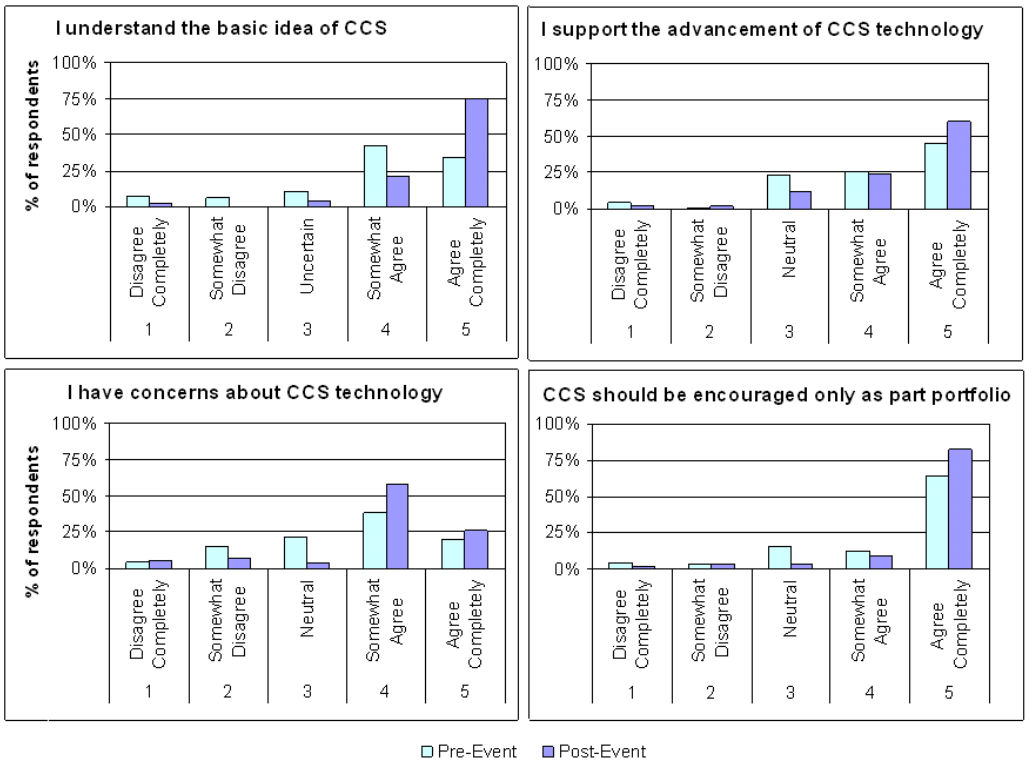

Figure 2: Respondent answers, both pre-event (lighter) and post-event (darker), to the four quantitative questions in the first section of the survey.

A person's prior education might influence his or her capacity to absorb, and learn from, new information. The results demonstrate that both those with graduate level education and those with a college-level education had a significant increase in their understanding of CCS. Wilcoxen tests limited to just those who reported graduate-level education were significant at 1%, and tests with those who reported graduate-level education were significant at 5%. It was not possible, however, to determine if there was a trend related to level of understanding and education level. Ninety-four percent of the respondents had at least a college education, and there was not enough variance in the responses for the standard deviations to indicate significant differences in level of understanding related to prior education level. Similarly, the increase in understanding cannot be attributed to a subset of the population by age, regardless of how the age bins in **Figure 2** are parsed or categorized. Responses from both genders indicate a significant increase in understanding at p<1% (Wilcoxen, n=15 for women, n=34 for men).

For question #2, analysis of the results shows that there was a significant increase in support for the advancement of CCS (Wilcoxen, p<5%, n=57). Unlike question #1, which asked about level of understanding of CCS, we do find significant differences based on level of prior education. Those who reported a graduate level education significantly increased their support for the advancement of CCS (Wilcoxen, p<1%,n=36), whereas those who reported less than a graduate level education did not (Wilcoxen, p<83%, n=21). Similarly, it appears as though the increase in support is driven by those between the ages of 40 and 59 (Wilcoxen, p<5%, n=28). While those aged 60-75 did not significantly change their answers (Wilcoxen, p<13%, n=18), neither did those older than 59 (Wilcoxen, p<16%, n=23), but those younger than 60 did (Wilcoxen, p<5%, n=34). Just as was the case for level of

understanding, the increase in support for CCS cannot be attributed to gender differences (Wilcoxen, Men: p<16%, n=34; Women p<12%, n=15).

In question #3, we do not find an increase in concerns about CCS technology in aggregate. We also do not find any significant differences in level of reported concern about CCS associated with age or education. Interestingly, however, there seems to be a marked difference in level of concern in CCS associated with gender. Responses by women indicate a significant increase in level of concern about CCS technology after the event (Wilcoxen, p<5%, n=14), whereas the responses of the male participants does not show this increase (Wilcoxen, p<61%, n=34).

Agreement that CCS should only be deployed as a part of a portfolio of mitigation measures increased somewhat significantly (Wilcoxen, p<10%, n=56). It appears as though this change was driven by those with less than a graduate level education (Wilcoxen, p<10%, n=20), because those with a graduate level education did not have significant change in their responses (Wilcoxen, p<43%, n=36). Neither age nor gender appear to have significant effect on this increase in agreement that CCS should be included only as a part of a portfolio of mitigation measures.

Table 1: Pairwise Correlations of Quantitative Responses on Pre- and Post-Event Surveys

		PRE-EVENT				POST-EVENT			
		1. Understand	**2. Support**	**3. Concerns**	**4. Portfolio**	**1. Understand**	**2. Support**	**3. Concerns**	**4. Portfolio**
PRE-	**2. Support**	0.4912***							
		(0.0000)							
	3. Concerns	0.1814*	-0.0752						
		(0.0965)	(0.4911)						
	4. Portfolio	0.2473**	0.0731	0.5254***					
		(0.0225)	(0.5062)	(0.0000)					
POST-	**1. Understand**	0.2336*	0.2319*	0.041	0.0323				
		(0.804)	(0.0825)	(0.7618)	(0.8116)				
	2. Support	0.0896	0.4757***	-0.0357	0.0098	0.5454***			
		(0.5075)	(0.0002)	(0.7923)	(0.9425)	(0.0000)			
	3. Concerns	0.2438*	0.0023	0.298**	0.1767	0.447***	0.068		
		(0.0702)	(0.9865)	(0.0257)	(0.1926)	(0.0005)	(0.6154)		
	4. Portfolio	-0.0006	-0.1438	0.1362	0.4986***	0.0097	-0.1317	0.3217**	
		(0.9963)	(0.2904)	(0.3170)	(0.001)	(0.9429)	(0.3287)	(0.0156)	
DEMOG	**6. Age**	-0.1342	0.1566	-0.1545	-0.1759	0.0107	0.2762**	-0.2383*	-0.2853**
		(0.2323)	(0.1600)	(0.2659)	(0.1163)	(0.9385)	(0.0432)	(0.0857)	(0.0384)
	7. Gender	-0.0093	-0.0553	-0.0101	0.0857	0.0717	-0.006	0.1851	0.1153
		(0.9405)	(0.6545)	(0.9350)	(0.4906)	(0.6245)	(0.9673)	(0.2078)	(0.4350)
	8. Education	0.1562	0.0692	0.0575	0.1026	0.4329***	0.2785**	0.3195**	-0.1184
		(0.1637)	(0.5366)	(0.6076)	(0.3619)	(0.0011)	(0.0414)	(0.0197)	(0.3986)

p-values in parentheses; significance indicated by *p>10%, **p<5%, ***p<1%

Table 1 presents the results of the pair-wise correlations. Answers to the question about participants' understanding of CCS remain highly correlated to their answers to the question about their support for the advancement of CCS technology. Respondents' answers regarding their understanding of CCS and its deployment in a portfolio become uncorrelated after the event. Respondents' answers to the question regarding concerns about CCS technology become more closely correlated with their reported level of understanding after the seminar than before it. Respondents' answers about their support for CCS technology are not correlated, either before or after the seminar, with their belief that CCS should only be deployed in a portfolio of mitigation options. Respondents' level of reported concern about the technology, however, remains correlated with respondents' support for its inclusion in a portfolio. Support becomes uncorrelated with prior understanding. Finally, after the seminar respondents' belief that CCS should only be included in a portfolio of mitigation options is not correlated with their level of prior concern, however these two responses are correlated before the seminar.

The pre-event surveys indicate that none of the demographic variables of interest (age, gender, education) are significantly correlated with any of the four questions. After the seminar, however, age becomes highly correlated with understanding, somewhat correlated with concerns, and negatively correlated with the portfolio

question. Additionally, education level becomes highly correlated with understanding, and significantly correlated with both support for, and concerns about, CCS. No significant correlations with gender emerge.

5. Conclusions and Discussion

This analysis demonstrates that exposure to information from experts about CCS technology increases stakeholder understanding and support for the technology. Further, these results suggest that those who understand CCS tend to support the advancement of the technology. While individual stakeholder concerns did not increase with exposure to information, the agreement that CCS should be deployed only as a part of a portfolio of climate mitigation options did increase somewhat after the seminar. This suggests that there may be vague concerns prior to the exposure to information and, as more is learned, specific issues to support those concerns are identified. Support for CCS may still exist, but with the qualification that it be among many tactics used to mitigate climate change.[4]

It appears as though some of the apparent changes in perceptions can be attributed to individual stakeholder learning and some of the changes can be attributed to shifts within the composition of the subgroups of the stakeholders at the seminar. It appears as though the increase in understanding is related to a correlation with education, even though it cannot be attributed to changing perceptions by individual highly-educated stakeholders. A correlation between concerns and education also develops. Also, it appears as though individuals who do not have a graduate education slightly increase their agreement with the notion that CCS should only be part of a portfolio of approaches to mitigate climate change, as an anti-correlation develops between age and this portfolio agreement.

Two results seem particularly interesting. First, highly-educated stakeholders and younger stakeholders increased their level of support for CCS as they are exposed to more information, while older stakeholders and less-educated individuals did not change their level of support. This result could indicate variation associated with age and level of education in the likelihood that any individual will change their mind when given more information. This result could also indicate that older people and less-educated people may have a deeper skepticism of or mistrust in CCS technology, so, despite the additional information their level of support, did not increase significantly.

A second interesting result is the increase in level of concern about CCS after the seminar by female attendees. This gender difference is striking, and may be one of the first identifications of a gender difference in perceptions of CCS technology. A higher degree of scepticism in new technologies by females than males is not surprising, however, as is consistent with other studies on gender and technology. To further explore this gender difference, a review of the gender and technology literature will be conducted and will be included in a subsequent more in-depth analysis and discussion of these results.

We acknowledge that a different survey design could have elicited slightly different results. The absolute ranking (on a scale of 1-5) left no room at the ends of the spectrum for changes more extreme than the initial response. If the respondents had been asked in the post-event survey how their perceptions changed relative to those they had at the beginning of the day, changes such as these could have been elicited.

A major issue that emerged during the CCS seminar was that none of the experts could identify potential CO_2 storage locations in, or proximal to, Maine. As a result, the potential for CCS with Twin River, and in Maine in general, is low. This concern is mentioned in the quote at the beginning of this paper. This context complicates the interpretation of respondents' support for CCS at the seminar. Potential CO_2 storage locations are an important aspect of CCS technology, and the lack of obvious storage locations in Maine, or even in the entire Northeast region, may have been influential in the perceptions of CCS. Neither the project developer nor any of the speakers could identify specific CO_2 storage locations in the Northeast; several panelists explained that there are, at present, no known onshore formations in the northeast United States that are amenable to geologic storage of CO_2. Some offshore options might exist, but the current state of knowledge does not include any known storage prospects. Respondents' strong level of support for CCS technology in general, therefore, must be interpreted with the caveat that participants may have concluded that storage of CO_2 was not likely in, or proximal to, Maine. As such,

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[4] It is possible that respondents may have been confused by the portfolio question and inadvertently missed the emphasis on "only" a part of a portfolio. As such, the somewhat significant increase in agreement that CCS should be part of a portfolio of options might not be driven by its inclusion with alternatives.

respondents could have been more supportive of the technology at the end of the event in part because they learned during the day that the long-term storage of CO_2 is unlikely to affect them.

It is known from previous experiences and previous studies, that perceptions and concerns are different for a general audience who is considering CCS in the abstract, versus a specific community that is considering the possibility of CCS in their region (Bielicki and Stephens 2008). It is possible that the day-long CCS seminar held in Maine, changed some individual's conception of whether CCS is something they need to consider that may be implemented in their region or something that they need to consider more abstractly as a potential climate change mitigation strategy that will be deployed elsewhere.

Our analysis here suggests that people changed their perceptions about CCS technology as they learned more about it. The Chewonki seminar was organized to educate people about CCS in Maine, in response to the proposal to build a coal/biomass-fueled power plant. Shortly after the Chewonki seminar, in November 2007, a height variance necessary for this plant did not pass a public vote (Gibbs 2007). Further, in April 2008, Maine's governor signed a bill that enacted a temporary ban on the construction of coal-fired facilities in Maine that requires the Maine Board of Environmental Protection to create standards for the emission and capture of carbon dioxide by August 2011 (Erskine 2008). We cannot, and do not, suggest that these developments were a result of the Chewonki seminar, in part because opposition to the Twin River facility incorporated many concerns not related to CCS,[5] and concerns related to the conditions specific to Maine's existing energy infrastructure.[6] But CCS technology can be perceived to prolong reliance on coal as a primary energy source. So while we do not claim that the seminar and the changed perceptions we document here led to the public actions against coal-fired facilities, we do believe, to some extent, that they may be related.

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[5] Such as the anticipated impact of increased barge traffic on lobstering and the relief by local residents that the former power plants at the proposed had finally been decommissioned and were no longer located in Wiscasset.

[6] At the time of the proposal, Maine was a net *exporter* of electricity and, as a state, had virtually no CO_2 emissions.

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